§6. First Cool-Down of An SC Current Feeder System for the LHD

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A superconducting (SC) current feeder system was constructed as the current transmission lines for the experimental fusion device, LHD. It consists of nine flexible SC bus-lines, nine pairs of current-leads, sub-cooler tanks, cryogenic valves and their controllers. The average distance between the SC coils of the LHD and their power supplies is 55 m. The rated current and withstand voltage are 32 kA and dc 5 kV at 77 K, respectively. First cool-down of the LHD started in February 23, and all SC coils including SC bus-lines became cryostable conditions on March 18. Typical waveforms of voltages on the SC bus-lines are shown in Fig. 1. Experiments for the plasma confinements were performed from March 31 to May 17. Total shot numbers of plasma production were 1888, and total times of the coil excitations were 692 hours.

The cold mass of the LHD and SC current feeder systems are 820 and 13 tons, respectively. To keep the uniformity of the thermal contraction, the SC current feeder system and the cryogenic components of the LHD were cooled down simultaneously. Thermal contraction of the SC cable has been estimated to be 180 mm, when the SC bus-lines are cooled. This shrinkage was designed to be absorbed in the structures of the SC bus-lines: (1) The SC cable and inner corrugated tubes were made longer than the outermost tube. (2) The structures of the terminals of the current-lead side enable to absorb the thermal contraction of the SC cable. and (3) The bending potions in the installation routes also enable to absorb the thermal contraction. These countermeasures are listed in Table 1. Heat loads into the SC bus-lines and current-lead cryostats were measured by the calorimetric method. Normalized heat load at 80 K into the SC bus-lines are shown in Fig. 2. Vacuum pressures of the SC bus-lines and cryostats were monitored continuously. Mode changes of coil excitations for the plasma experiments, power shut-down tests for the coil protection and long term excitation for the discharge cleaning (five days) were also carried out in this experimental period.

Cool-down and current carrying properties of the SC current feeder system were investigated. The results are summarized as follows:

(a) Normalized heat loads into nine SC bus-lines at 80 K was 2.8 W/m, and the average heat input into the current-lead cryostats was 5.4 W/m^2. These values are less than these of design values.

(b) Mass flow rates, pressures and liquid helium levels of the SC bus-lines and current-leads are well controlled automatically in the steady state operation.

(c) We have demonstrated successfully that the SC current feeder system with high current capacities was useful for the SC experimental fusion device.

Table 1 Thermal shrinkage of the SC cables and their absorptions

Conditions	Parameters
Length of the SC bus-lines	55 m (Av.)
Thermal shrinkage length of SC cables	181 mm
Absorptive length for thermal contraction	
Over length of the SC cables	>117 mm
Terminal of the current-lead side	200 mm
Bending parts in the route	>113 mm

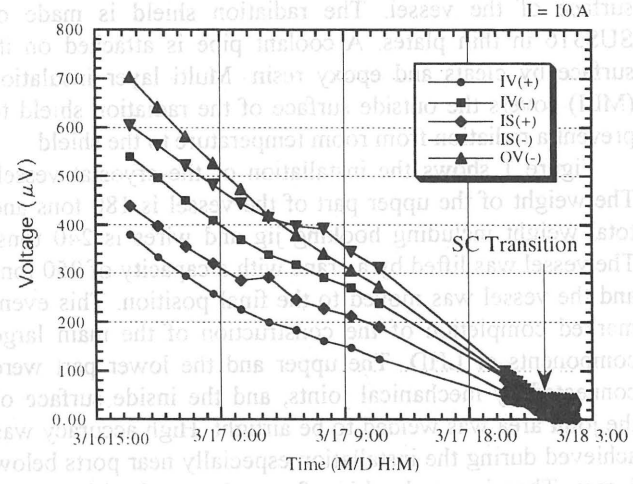

Fig.1 Typical waveforms of voltages between the SC cable.

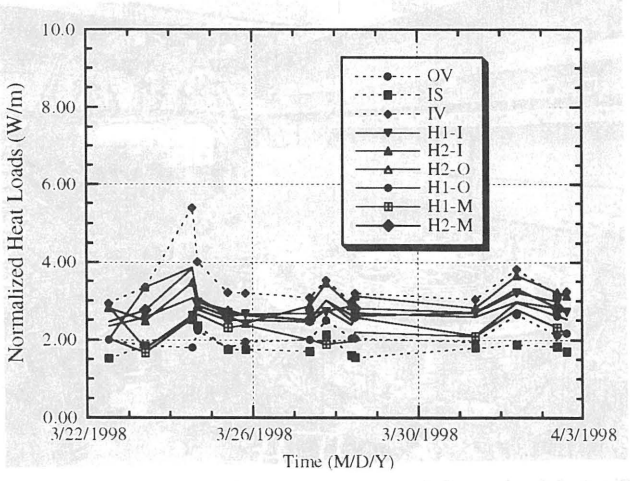

Fig.2 Measured heat load at 80 K into the SC bus-line.